

State of the Art in Improved Nyquist Filters

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In 1928 Nyquist gave first Nyquist criterion for zero intersymbol interference (ISI) level. He showed that the ideal brick-wall filter can be replaced with a real one having a frequency characteristic that shows odd vestigial symmetry around the cut-off frequency.

A long time the research was centered on finding filter transfer functions $H(f)$ that are continuous and possess a large number of derivatives that are also continuous and equal to zero at the ends of the definition interval. This property results in an impulse response that decays very fast.

In 2001 Beaulieu e.a. introduced a novel ISI-free pulse referred to as better than raised-cosine (BTRC), flipped-exponential (fexp) or Parametric Exponential Pulse ($n=1$) [3]. This exhibits a more open receiver eye with smaller maximum distortion and a smaller probability of error in the presence of symbol timing error than the Nyquist pulse for the same excess bandwidth and was characterized as an improved Nyquist filter (INF).

In a practical receiver the synchronization circuit is affected by jitter produced by noise, tracking error, distortion, multipath propagation and Doppler effect and the information are recovered by real sampling that take place at time instants that fluctuate around ideal time instants, thus generating ISI. The improvement refers to the fact that using an INF its performance is superior to the “Raised Cosine” (RC) pulse, as its impulse response has smaller maximum sidelobes, smaller maximum distortion, and a smaller error probability in the presence of timing jitter for the same excess bandwidth α . The pioneering works on this subject are due to L. E. Franks [1] and F. S. Hill Jr. [2]. The concept of improved Nyquist filter (INF) and the construction of parametric families originate with the work of Beaulieu et al.

The frequency characteristic of the filter is split evenly between the transmitter and the receiver filter. The identical square-root Nyquist filters are digitally implemented with a truncated oversampled causal version, which determines spectral regrowth and increased error probability, as compared with its infinite replica. The truncation length should be kept as small as possible in order to minimize the implementation costs and the propagation delay of the DSP part.

In order to achieve both good spectral performance and error probability performance, the price to pay is increased hardware complexity (more silicon area) but this conflicts with the propagation delay of the DSP part.